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# COMMUNITY STRUCTURE CHARACTERISTICS OF PHYTOPLANKTON IN ZHALONG WETLAND, CHINA

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**Abstract**

In autumn 2010, the phytoplankton samples were collected in Zhalong Wetland. A total of 347 species belonging to 78 genera, 6 phyla were identified, Chlorophyta and Bacillariophyta were dominated phytoplankton communities, including 143 species of Chlorophyta, 116 species of Bacillariophyta, 45 species of Cyanophyta, 39 species of Euglenophyta, 3 species of Pyrrophyta, 1 species of Chrysophyta. In the core area 66 genera, 222 species were identified, in the buffer area 63 genera, 210 species were identified, in the experiment area 63 genera, 167 species were identified. The dominant species in Zhalong Wetland included *Cyclotella meneghiniana*, *Chlorella vulgaris*, *Trachelomonas volvocina*, *Nitzschia* sp.. The average phytoplankton density was $12.13\times10^{6}$ind·L$^{-1}$ in Zhalong Wetland, the phytoplankton density of Bacillariophyta was highest ($32.82\times10^{6}$ ind·L$^{-1}$), and then Chlorophyta ($23.73\times10^{6}$ ind·L$^{-1}$) and Cyanophyta ($11.43\times10^{6}$ind·L$^{-1}$), respectively. The results of cluster analysis showed that phytoplankton community structure could be divided into three types, and within-group similarities of phytoplankton community structure was not high, but inter-group non-similarity was high. Based on the species composition, phytoplankton density, phytoplankton pollution indicator, it suggested that Zhalong Wetland was mesotrophic state.

**key words:** Community structure, phytoplankton, Chlorophyta and Bacillariophyta, Euglenophyta, Pyrrophyta.

## Introduction

Our world especially developing countries are facing the problem of water stress due to rapid growth in population (Chughtai, 2013), and the water quality has a direct effect on people's health (Chow *et al.*, 2012; Rizvi *et al.*, 2012; Tanik *et al.*, 2013; Parmar *et al.*, 2013). Phytoplankton, as one important part in water ecosystem, is not only main contributor to aquatic primitive productivity, but also basic segment of food chain (Nazneen, 1974; Chattopadhyay *et al.*, 2003). It plays an important role in material recycling and energy transformation and is the major starting point of aquatic ecosystem. The change of its composition and diversity may directly affect the structure and function of aquatic ecosystem (Cardinale *et al.*, 2002). The community structure, quantity and diversity of phytoplankton is one of the most important parameters to assessing aquatic quality and meanwhile to reflecting its pollution circumstances (Polat *et al.*, 2002; Cardosoa *et al.*, 2002; Balkis *et al.*, 2004; Devercellia & O'Farrell, 2012; Domingues *et al.*, 2012).

Zhalong Wetland located in the west of Hei Longjiang province and in the southeast of Qiqihar city, reserved the majority of its initial northern China, which included the wetland diverse ecological system. It was listed into the List of international Important Wetlands in 2002, and concerned by international community extensively as wetland nature reserve with high biodiversity (Mitsch & Gosselink, 2003). Only a few decades, with regional climate change and human activities heavily influenced, the ecological pattern of Zhalong Wetland had been profoundly changed that wetland area decreased, water quality gradually deteriorated, ecological environment deteriorated, ecological function declined, biodiversity got threatened.

The objectives of the current study were to: (1) identify the phytoplankton species, community structure and phytoplankton biodiversity, (2) analysis the phytoplankton community structure, and (3) assessment the water quality by analysis the phytoplankton dominant species, pollution indicator species, Shannon Wiener index, Margalef index and phytoplankton density in Zhalong Wetland. This work provided theoretic basis data for spatial grading of service functional values of ecology and wetland ecosystem conservation and utilization in Zhalong Wetland.

## Materials and Methods

**Study area:** The Zhalong Wetland is located on Songnen Plain of the Songhua River Basin, lower reaches of Wuyu'er River, in the west Heilongjiang Province, China. It is approximately 2,100 km$^2$ located within latitudes 46°52′N to 47°32′N and longitudes 123°47′E to 124°37′E, and is in a temperate continental monsoon climate zone (Qin *et al.*, 2009). The average altitude is approximate 144.0 m, the mean annual temperature is 3.9°C and the mean annual precipitation is approximate 420 mm (Yi *et al.*, 2004; Zhao, 2005). Marshes, rice paddy fields are the main habitat types in the wetland, and reed marsh covers 80～90 % of the area. In order to better manage the Zhalong Wetland in 2001 it was divided into the core zone, buffer zone, and experimental zone (Qin *et al.*, 2009). The sample was collected from July to August 2010 and 293 sampling sites were positioned by GPS over the most area of Zhalong Wetland, 126 sites in core area, 104 sites in buffer zone and 63 sites in experimental area (Fig. 1).

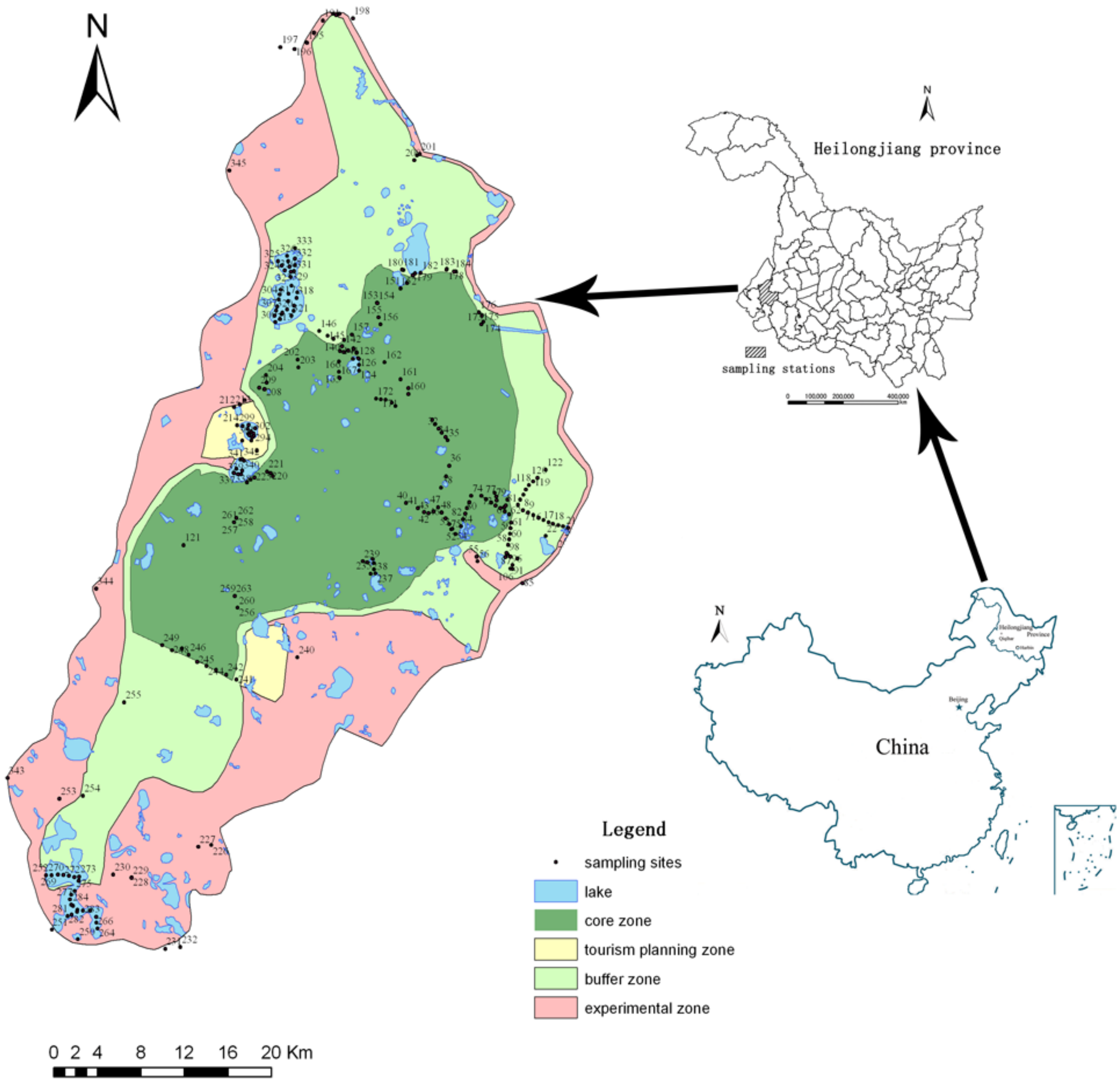


Fig. 1. The distribution of sampling sites in this study in Zhalong Wetland, Heilongjiang Province, China, 2010.

**Phytoplankton qualitative and quantitative samples:** Phytoplankton samples were collected twice from the same sites. The collection was conducted from the surface water to a depth of 0.5 to 1.0 m using plankton net (26µm mesh size) and then preserved in 4% formaldehyde. Collected samples were transported to the Geography Laboratory at Harbin Normal University, Harbin, China, and transferred to 1000mL bottles. After fixing with 10mL Lugol's iodine solution and sedimentation for 48 h, the phytoplankton samples were concentrated to 30 mL, mixed, and 0.1 mL concentrated samples were counted using an Olympus optical microscope at 400×. Phytoplankton was identified to genus or species, and at least 300 phytoplankton cells were counted per sample, classification and identification of phytoplankton species and genus were based on Krammer and Lange-Bertalot (1986), Shameel (2001), John (2003) and Hu *et al.* (2006).

**Biological diversity index:** According the study resource was divided into 4 types (Palmer, 1969), that was oligosaprobic, α-mesosaprobic, β-mesosaprobic and polysaprobic zone through analysis on water state using phytoplankton pollution indicator species. After quantitative phytoplankton analyses was used for calculations of diversity index. Shannon-Wiener index and Margalef index were used (Krebs, 1989; Xu, 2008).

Margalef index is defined as:

$$D = \frac{S - 1}{\ln N} \qquad (2\text{-}1)$$

where S is the total number of phytoplankton, N is the proportional abundance of phytoplankton, D is the Margalef index Shannon-Weaver index is defined as:

$$H = -\sum_{i=1}^{s}\left(\frac{n_i}{N}\ln\frac{n_i}{N}\right) \quad (2\text{-}2)$$

where N is the total number of species, $n_i$ is the proportional abundance of ith species and, H is the Shannon-Wiener diversity. Among which, H refers to diversity index; $n_i$ is individual number of species i; N means total phytoplankton number.

**Statistical analysis:** Spatial distribution mapping of phytoplankton density, Shannon index and Margalef index using ordinary Kriging were performed with the ArcGIS 9.3, commercial geographic information system software developed by ESRI Co, Redlands, USA. Phytoplankton community analysis using clustering analysis and multi-dimensional sorting analysis were performed with the software of PRIMER 5.0.

## Results and Discussion

**Spatial distribution of phytoplankton community:** The results of phytoplankton in autumn 2010 showed that the species were various and their composition was complicated. The phytoplankton was identified 347 species, belonging to 6 phyla, 8 classes, 21 orders, 33 families and 78 genera (Fig. 2). It can be identified from phytoplankton composition that the dominant community was Chlorophyta (41.2%); and then Bacillariophyta (33.4%); Cyanophyta (13.0%); Euglenophyta (11.2%), respectively. Pyrrophyta, Cryptophyta and Chrysophyta were a relatively small percentage of total species.

In the core area of Zhalong Wetland, phytoplankton was identified 66 genera, 222 species, included Chlorophyta was 33 genera, 98 species; Bacillariophyta was 20 genera, 69 species; Cyanophyta was 7 genera, 34 species; Euglenophyta was 4 genera, 19 species; Pyrrophyta was 1 genus, 1 species. In the buffer zone 63 genera, 210 species were identified, included Chlorophyta was 31 genera, 86 species; Bacillariophyta was 19 genera, 75 species; Cyanophyta was 9 genera, 23 species; Pyrrophyta was 2 genera, 2 species; Chrysophyta was 1 genus, 1 species. There were 63 genera, 167 species in experimental area, included Chlorophyta was 25 genera, 76 species; Bacillariophyta was 19 genera, 47 species; Cyanophyta was 8 genera, 21 species; Euglenophyta was 5 genera, 19 species; Pyrrophyta was 3 genera, 3 species; Chrysophyta was 1 genus, 1 species. As functional areas changed, the dominant species were different compositions and structures (Table 1). The major dominant species during Zhalong wetland included *Cyclotella meneghiniana*, *Chlorella vulgaris*, *Trachelomonas volvocina* and *Nitzschia* sp. and so on.

The average density of phytoplankton in Zhalong Wetland was $12.13\times10^6$ind·L$^{-1}$. The Bacillariophyta was the greatest density ($32.82\times10^6$ ind·L$^{-1}$), 45.1% of total phytoplankton density; the density of Chlorophyta was second ($23.73\times10^6$ind·L$^{-1}$ , 32.6% of total phytoplankton density); the Cyanophyta was third ($11.43\times10^6$ind·L$^{-1}$, 15.7% of total phytoplankton density); and then the Euglenophyta ($4.51\times10^6$ ind·L$^{-1}$, 6.2% of total phytoplankton density); the Pyrrophyta ($0.18\times10^6$ ind·L$^{-1}$, 0.25% of total phytoplankton density); the Chrysophyta ($0.06\times10^6$ ind·L$^{-1}$, 0.08% of total phytoplankton density), respectively (Fig. 3).

The monitoring result of phytoplankton in Zhalong Wetland showed that there was heterogeneity for phytoplankton in spatial distribution. The species richness of phytoplankton species in core area was the most (222), and then the buffer zone (210), the experimental area (167). The richness of Chlorophyta and Bacillariophyta were important component of three areas, which showed the study region in Zhalong Wetland was the Chlorophyta - Bacillariophyta type, they can adapt to changeable ecological environment (Nalewajko & Murphy, 2001; Licursi *et al*., 2006), and this community structure belonged to mesotrophic state (Yang *et al*., 2008). The result showed there was difference of phytoplankton community structure with different regions in Zhalong Wetland. The phytoplankton density was in experimental area>buffer zone>core area, was mainly due to different water environment. In experimental area, Lin Dian country directly discharged sewage of industrial and domestic and human's activities affected water quality and exacerbate many forms of water pollution, so the richness of phytoplankton species decreased and phytoplankton density was increased. In buffer zone, the phytoplankton species relatively increase by purifying effect of aquatic plants. In core area, human's activities had a little affect water quality. The broad rich mass of wetland plants, especially reeds, can be effective in purify water quality and the richness of phytoplankton species was higher, the phytoplankton density was lower.

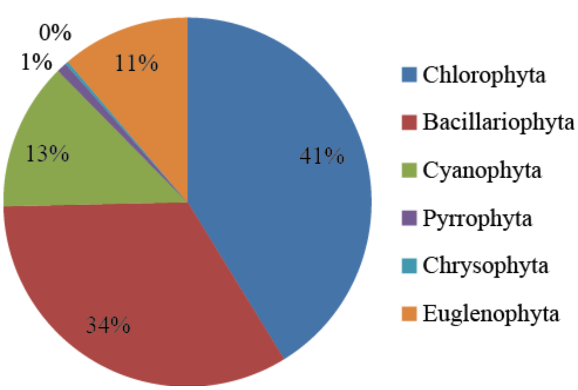


Fig. 2. The composition of phytoplankton community in Zhalong Wetland, Heilongjiang Province, China, 2010.

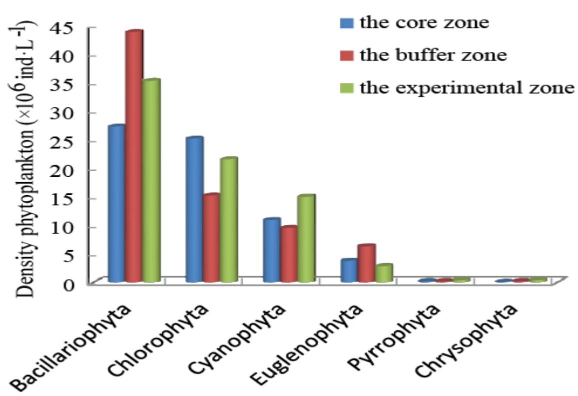


Fig. 3. Distribution of phytoplankton density in Zhalong Wetland, Heilongjiang Province, China, 2010.

**Table 1. Dominant species of phytoplankton in Zhalong Wetland, Heilongjiang Province, China, 2010.**

| Region | Dominant species | Relative abundance | Frequency of occurrence | Coverage |
|---|---|---|---|---|
| Core zone | *Gomphonema* sp. | 1.25 | 0.46 | 0.58 |
| | *Navicula radiosa* | 0.89 | 0.54 | 0.48 |
| | *Rhopalodia gibba* | 0.41 | 0.69 | 0.28 |
| | *Chlorella vulgaris* | 0.31 | 0.69 | 0.21 |
| | *Nitzschia* sp. | 0.31 | 0.46 | 0.14 |
| | *Navicula* sp. | 0.29 | 0.46 | 0.13 |
| | *Cocconeis placentula* | 0.27 | 0.38 | 0.10 |
| | *Eunotia lunaris* | 0.26 | 0.54 | 0.14 |
| Buffer zone | *Cyclotella meneghiniana* | 0.63 | 0.38 | 0.24 |
| | *Chlorella vulgaris* | 0.59 | 0.75 | 0.44 |
| | *Trachelomonas volvocina* | 0.49 | 0.63 | 0.31 |
| | *Nitzschia* sp. | 0.45 | 0.31 | 0.14 |
| | *Gyrosigma acuminatum* | 0.39 | 0.38 | 0.15 |
| | *Melosira varians* | 0.38 | 0.19 | 0.07 |
| | *Selenastrum minutum* | 0.37 | 0.31 | 0.11 |
| | *Aulacoseira granulata* var. *angustissima* | 0.33 | 0.25 | 0.08 |
| | *Fragilaria capucina* | 0.26 | 0.38 | 0.09 |
| Experimental zone | *Ceratium hirundinella* | 0.87 | 0.63 | 0.55 |
| | *Aulacoseira granulata* | 0.49 | 0.38 | 0.19 |
| | *Melosira varians* | 0.34 | 0.50 | 0.17 |
| | *Trachelomonas volvocina* | 0.19 | 0.63 | 0.12 |
| | *Cyclotella meneghiniana* | 0.20 | 0.25 | 0.05 |
| | *Chlorella vulgaris* | 0.17 | 0.75 | 0.13 |
| | *Nitzschia sublinearisoides* | 0.11 | 0.25 | 0.03 |
| | *Microcystis flosaquae* | 0.10 | 0.50 | 0.05 |

**Phytoplankton community analysis:** When the dendogram was analysed the similarity between the stations in terms of phytoplankton species was produced (Fig. 4). It can be divided into 3 groups through the clustering analysis of phytoplankton species (Fig. 5). The result of multi-dimensional scaling analysis showed that the pressure coefficient was 0.19, it was a reliable result explaining the similar relationship between species. The community contributing more can be concluded through the analysis on major contributor by SIMPER analysis (Table 2).

SIMPER analysis that average similarity of group F1 was 50.43% and the main representative species were *Ceratium hirundinella*, *Melosira varians* and so forth. Average similarity of group F2 was 40.12% and the main representative species were *Fragilaria capucina*, *Chlorella vulgaris* and so forth. Average similarity of group F3 was 39.01% and the main representative species were *Eunotia lunaris*, *Cocconeis placentula* and so forth.

Different water qualities by trophic state index were different phytoplankton community structures and dominate species (Negro *et al.*, 2000). Through analysis, phytoplankton species in Zhalong Wetland were able to divided into 3 groups, the majority of group F3 sampling sites were in core area where human activities was relatively small, the coverage of aquatic plants was larger and the self-purification capacity of the water environment was increased. The oligosaprobic indicators were appeared, such as *Eunotia lunaris* and *Navicula radiosa* etc. *Navicula radiosa*, once reported was the most common species and lived in neutral water with middle electrical conductivity (Gasse, 1986), Krammer & Lang-Bertalot (1986) reported this species can live in cleanly water, and Lang-Bertalot (2001) reported it was living in poorly or moderately eutrophication and in the sewage; all these illustrate that *Navicula radiosa* was a wide ecological amplitude. Although water environment were different during sampling stations in the study, *Navicula radiosa* can be taken as oligosaprobic indicator species according to its sampling site distribution characteristics. Group F1 and F2 were in the same class mainly in experimental area and buffer zone. In those areas, agricultural non- point pollution source, sewage of industrial and domestic flowed directly into Zhalong Wetland. Some mesotrophic and eutrophic indicator species were appeared such as *Cyclotella meneghiniana*, *Chlorella vulgaris*, *Ceratium hirundinella*, *Melosira granulate* and *Trachelomonas volvocina* etc. The *Trachelomonas volvocina* was living in high organic matters of water (Philipose, 1988), and a large bloom of this species was caused water quality to deteriorate severely. In the sampling sites of group F1, the Li Dian country had directly discharged into the wetland, caused the mass deaths of bird and fish and many eutrophic indicator species were appeared, such as *Chlorella vulgaris*, *Oscillatoria princeps*, *Microcystis aeruginosa* and *Fragilaria capucina*. The results showed that water quality of Zhalong Wetland was a great response from the different phytoplankton species and objectively reflected that phytoplankton can be used to assessment water quality.

**Table 2. Within-group similarities in Zhalong Wetland, Heilongjiang Province, China, 2010.**

| Species | F1 | F2 | F3 |
|---|---|---|---|
| *Cyclotella meneghiniana* | 11.06 | 5.03 | 2.54 |
| *Oscillatoria subbrevis* | 2.58 | 0.00 | 0.00 |
| *Ankistrodesmus acicularis* | 0.57 | 0.00 | 0.00 |
| *Anabaena azotica* | 2.78 | 0.00 | 0.86 |
| *Anabaena cylindrica* | 3.73 | 0.90 | 0.00 |
| *Ankistrodesmus falcatus* | 0.00 | 0.86 | 0.49 |
| *Ceratium hirundinella* | 0.00 | 15.29 | 0.00 |
| *Chroococcus heloeticus* | 0.00 | 0.96 | 0.91 |
| *Chlorella vulgaris* | 27.83 | 7.86 | 4.65 |
| *Cosmarium angulosum* | 0.00 | 0.00 | 0.00 |
| *Cosmarium blyttii* | 0.00 | 0.00 | 0.00 |
| *Coelastrum microporum* | 0.00 | 0.43 | 1.60 |
| *Cocconeis placentula* | 0.00 | 0.00 | 0.00 |
| *Cosmarium subcucumis* | 0.00 | 0.51 | 0.00 |
| *Cymbella cistula* | 4.50 | 0.00 | 0.00 |
| *Cymatopleura solea* | 5.89 | 0.00 | 0.00 |
| *Cymbella ventricosa* | 0.00 | 0.00 | 0.35 |
| *Euastrum ansatum* | 0.00 | 0.00 | 0.00 |
| *Eunotia lunaris* | 0.00 | 0.00 | 0.00 |
| *Fragilaria capucina* | 7.88 | 0.00 | 4.57 |
| *Nitzschia lorenziana* | 0.00 | 0.00 | 0.00 |
| *Ankistrodesmus convolutus* | 0.00 | 0.00 | 0.00 |
| *Gomphonema constrictum* | 0.00 | 0.47 | 0.00 |
| *Gomphonema parvulum* | 0.00 | 0.00 | 0.00 |
| *Gyrosigma acuminatum* | 3.11 | 0.00 | 2.36 |
| *Kirohneriella obesa* | 0.00 | 0.00 | 0.66 |
| *Lyngbya* sp. | 0.00 | 0.00 | 0.00 |
| *Merismopedia elegans* | 0.00 | 0.45 | 0.00 |
| *Melosira granulate* | 0.00 | 6.75 | 0.00 |
| *Merismopedia minima* | 0.00 | 0.00 | 1.28 |
| *Melosira varians* | 0.00 | 7.56 | 5.20 |
| *Microcystis aeruginosa* | 11.50 | 0.00 | 1.08 |
| *Micrasterias* sp. | 0.00 | 0.00 | 0.00 |
| *Microcystis flosaquae* | 0.00 | 1.28 | 0.00 |
| *Gloeocapsa gigas* | 10.97 | 0.65 | 3.62 |
| *Navicula cryptocephala* | 0.00 | 1.75 | 0.00 |
| *Navicula cuspidata* | 3.75 | 0.00 | 0.00 |
| *Navicula radiosa* | 0.00 | 0.00 | 2.39 |
| *Navicula salinarum* | 0.00 | 0.00 | 1.11 |
| *Microcystis marginata* | 2.50 | 0.00 | 0.00 |
| *Nitzschina palea* | 10.03 | 0.00 | 0.00 |
| *Nitzschia* sp. | 9.63 | 4.08 | 3.44 |
| *Oscillatoria granulata* | 0.00 | 0.00 | 0.00 |
| *Oscillatoria princeps* | 0.00 | 0.00 | 0.00 |
| *Pediastrum boryanum* | 0.00 | 1.38 | 0.00 |
| *Phacus peteloti* | 0.00 | 0.55 | 0.00 |
| *Rhopalodia gibba* | 0.00 | 0.00 | 0.78 |
| *Scendesmus acutiformis* | 0.00 | 0.00 | 0.73 |
| *Scenedesmus arcuatus* | 0.00 | 3.07 | 0.00 |
| *Scenedesmus quadricauda* | 0.00 | 0.00 | 0.63 |
| *Selenastrum minutum* | 1.55 | 0.00 | 2.33 |
| *Microcystis robusta* | 0.00 | 0.00 | 1.21 |
| *Ulnaria ulna* | 0.00 | 0.00 | 1.07 |
| *Trachelomonas oblonga* | 0.00 | 0.00 | 1.06 |
| *Trachelomonas subcoronetta* | 0.00 | 0.49 | 0.56 |
| *Trachelomonas volvocina* | 5.40 | 1.20 | 1.60 |

Where F1 is the experimental area, F2 is the buffer area, F3 is the core area

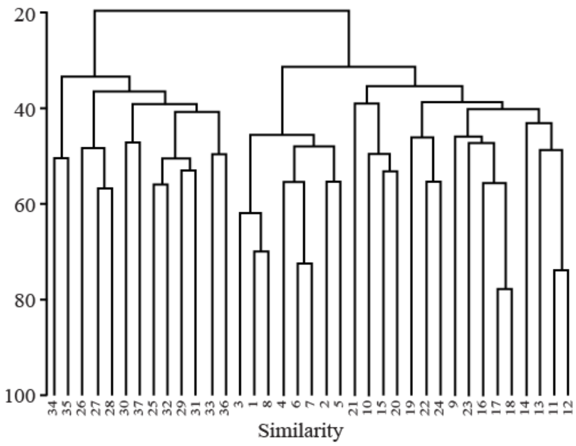


Fig. 4. Cluster analysis of phytoplankton abundant in Zhalong Wetland, Heilongjiang Province, China, 2010.

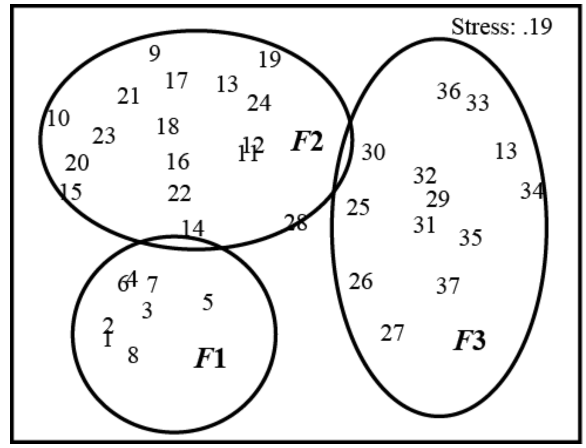


Fig. 5. MDS analysis of phytoplankton abundant in Zhalong Wetland, Heilongjiang Province, China, 2010.

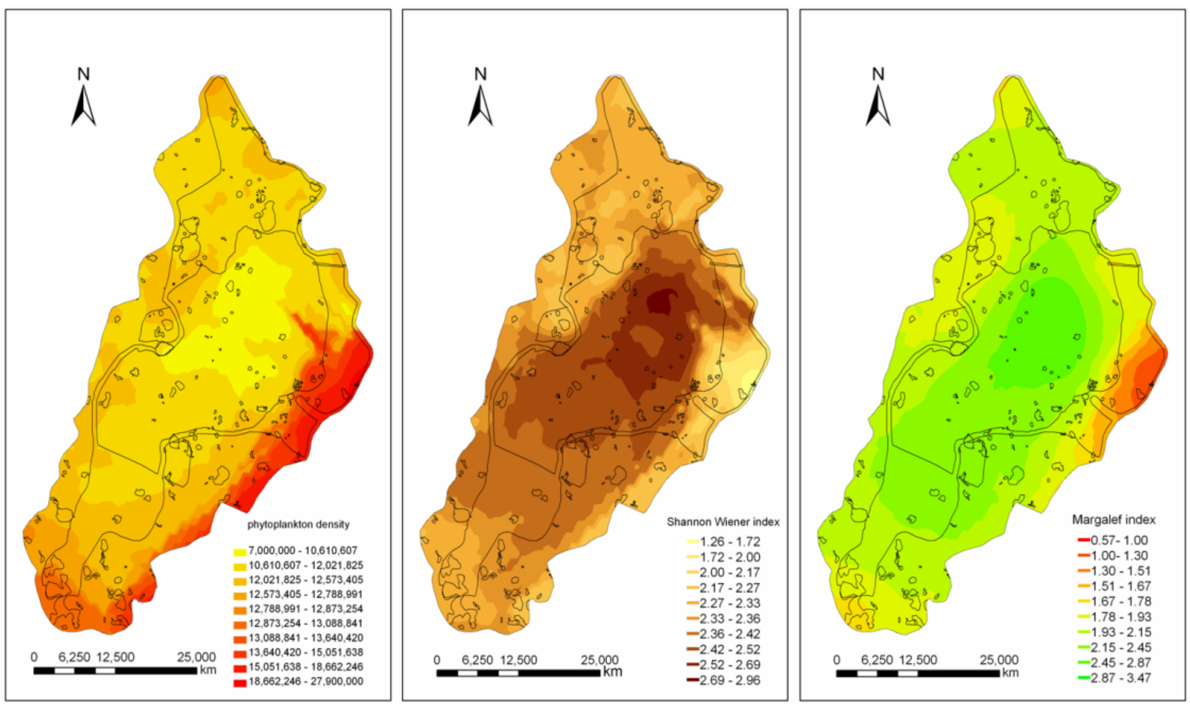


Fig. 6. Phytoplankton density and diversity index of Zhalong Wetland, Heilongjiang Province, China, 2010.

**Water quality assessment:** In the composition of phytoplankton species in Zhalong Wetland, there were 7 indicator species in oligosaprobic zone, 21 indicator species in β-mesosaprobic zone, 12 indicator species in α-mesosaprobic zone, 1 indicator species in polysaprobic zone, this result showed that most of phytoplankton species belong to β-mesosaprobic zone and α-mesosaprobic zone and a few phytoplankton species belong to oligosaprobic zone. In core area a lot of oligosaprobic indicator species were appeared such as *Cosmarium meneghinii*, *Eunotia lunaris* and *Nitzschia gracilis*. In experimental area there were mesosaprobic indicator species such as *Trachelomonas volvocina*, *Pandorina morum*, *Cyclotella meneghiniana* and *Oscillatoria princeps*. According to documentary recorded (Palmer, 1969), *Oscillatoria princeps* was barely appeared in oligosaprobic zone but possibly existed in polysaprobic zone, it showed that experimental area was certain pollution. During study, mesosaprobic indicator species of phytoplankton was in the majority, which showed the water quality was in the mesotrophic state in Zhalong Wetland.

The phytoplankton density in Zhalong Wetland ranged from $7\times10^6$ ind $\cdot L^{-1}$to $27.9\times10^6$ ind $\cdot L^{-1}$, in which oligosaprobic-mesotrophic take up 8.57% and mesotrophic take up 91.43%, the results showed that the water quality was in mesotrophic state. The diversity analysis showed (Fig. 6) that the minimum values of Margalef index and Shannon-Weaver index were in experimental area and the maximum values of that were in core area. The diversity index (Cai, 2006) of Shannon-Weaver, ranged from 1.39 to 2.96, it showed that the water quality was mesotrophic state. The Margalef index was ranged from 0.82 to 3.47. According to the standard (Xu, 2008), clean water take up 5.71% of water environment, mild pollution was 25.71%, middle pollution was 65.71% and heavy pollution was 2.86%. The analysis result showed the majority of Zhalong Wetland water was in the state of middle pollution.

## Conclusion

1. In autumn 2010, 347 species were identified, belonging to 6 phyla, 78 genera in Zhalong Wetland. The richness of phytoplankton from core area, buffer area to experimental area successively decreases. Therein Chlorophyta was in majority, Bacillariophyta was the second, which can be primitively deduction was Chlorophyta - Bacillariophyta type.
2. In the study, average density of phytoplankton was $12.13\times10^{6}$ind$\cdot$L$^{-1}$. The phytoplankton density was highest in experimental area, and then in the buffer zone and in the core area, respectively. The density of Bacillariophyta was the highest in three study areas. The dominate species included *Cyclotella meneghiniana*, *Chlorella vulgaris*, *Trachelomonas volvocina* and so on.
3. The phytoplankton community can be divided into 3 groups by clustering and multi-dimensional scaling analysis. In the group F1 and F2, there were mesotrophic - eutrophic indicator species such as *Chlorella vulgaris*, *Oscillatoria princeps* and *Cyclotella meneghiniana*. In the group F3, there were oligosaprobic and mesotrophic indicator species such as *Eunotia lunaris* and *Micrasterias* sp. and so on.
4. The phytoplankton density, indicator species, pollution indicator species, Shannon Wiener index, Margalef index indicated that the water quality was a mesotrophic state in Zhalong Wetland.

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